

HOW DOES THE INTERIOR OF VENUS LOSE HEAT? D. L. Turcotte, Dept. of Geological Sciences, Cornell University, Ithaca NY 14853, USA.

Venus is expected to have concentrations of the heat-producing elements (U, Th, K) in its interior similar to the concentrations within the Earth. Measured surface concentrations of these elements on Venus [1] have confirmed this basic hypothesis. On the Earth $80 \pm 10\%$ of the surface heat loss is attributed to these heat-producing elements and the remainder is attributed to the secular cooling of the planet. The primary mode of heat transfer within the interior of the Earth is solid-state thermal convection. This convection is responsible for plate tectonics and the associated volcanism, seismicity, and mountain building. It is expected that solid-state convection is also the primary heat transfer mechanism within Venus.

On the Earth the subduction of oceanic lithosphere accounts for 70–75% of the heat loss from the Earth's interior. The average age of the subducted lithosphere is 125 ± 10 m.y. Clearly, continuous subduction of lithosphere on Venus does not contribute significantly to heat loss from the venusian mantle. Alternatively, it has been proposed that episodic, global subduction events occur on Venus [2–4]. If these events were to be directly responsible for cooling the interior of Venus, they would have to occur approximately every 125 m.y. in direct analogy to the Earth. However, cratering studies indicate that the last global subduction event occurred 500 ± 150 m.y. ago. Episodic global subduction events with a period near 500 m.y. can only account for about 25% of the required surface heat loss. If the episodic subduction hypothesis is correct, then a mechanism must be found for the remaining 75% of the interior heat loss.

After a global subduction event the asthenosphere on Venus would extend to the surface. Because the basalt liquidus is considerably steeper than the mantle adiabat, large degrees of partial melting and a very low mantle viscosity would be expected. Surface heat flows could be very high. In order to prevent a surface conductive layer from greatly reducing the surface heat flow it is necessary for surface layers to founder nearly as soon as they form. However, in order to be effective in cooling the planet as a whole, the foundering crust must mix and rehomogenize with the mantle. This is possible if the founder basaltic crust converts to eclogite so that it is gravitationally unstable with respect to the mantle.

A parameterized convection calculation has been used to constrain the thickness of the subducted lithosphere, the time during which the lithosphere thickens, and the instability responsible for the foundering of the lithosphere. A typical thickness of the foundering lithosphere would be 10 km and the thickening time 3 m.y. The necessary cooling would be accomplished in about 50 m.y. The primary variable determining this behavior is the viscosity of the asthenosphere.

The proposed behavior of Venus can be explained in terms of two modes of lithospheric instability. To a first approximation, lithospheric instability can be related to the Rayleigh number based on the thickness of the lithosphere and the viscosity of the asthenosphere beneath the litho-

sphere. If this Rayleigh number exceeds a critical value, instability and subduction can be expected. This instability is related to the ratio d_L^4/η_a (d_L = thickness of lithosphere, η_a = viscosity of asthenosphere); if this ratio exceeds a critical value lithospheric instability can be expected. The question is whether the thickness d_L^4 dominates, in which case thick lithosphere becomes unstable, or whether the variation in viscosity η_a dominates. If η_a for a thin lithosphere is several orders of magnitude less than for a thicker lithosphere, then there may be two modes of subduction as the system evolves.

During the long period of surface quiescence the interior of Venus would heat up at a rate of about $220^\circ\text{K G.y.}^{-1}$. Due to the increased thickness of the global lithosphere and the decreasing mantle viscosity, the global lithosphere eventually destabilizes and subducts. However, because of its great thickness it will take several hundred million years for the cold subducted lithosphere to heat up and thereby cool the mantle. Following the subduction event effective cooling of the planetary interior requires the foundering of relatively thin (~ 10 km) lithosphere, which could be entirely made up of basaltic crustal rocks.

Eventually the interior of the planet cools sufficiently that the surface layer stabilizes. This stabilization results in a period of "thin skin" tectonics and the formation of the highly deformed tessera terrain [5,6]. As the global lithosphere stabilizes, near-global volcanism continues, producing the relatively smooth volcanic plains. As the lithosphere continues to thicken, volcanic constructs develop.

Any comprehensive theory for the evolution of Venus must also explain the highlands. Some, such as Beta Regio, may be the result of present or recent volcanism and tectonism related to mantle plumes. But other highlands, such as Istar Terra, Alpha Regio, and Ovda Regio, may be fossil silicic remnants that survived the last global subduction event.

Another unique feature on Venus is the coronae. Most likely these are the surface signatures of mantle plumes. Artemis Chasma has a striking similarity to subduction zones on the Earth. It may represent an aborted global subduction event.

References: [1] Surkov Y. A. et al. (1986) *Proc. LPSC 17th*, in *JGR*, 92, E537. [2] Turcotte D. L. (1993) *JGR*, 98, 17061. [3] Turcotte D. L. (1995) *JGR*, 100, 16931. [4] Turcotte D. L. (1996) *JGR*, 101, 4765. [5] Basilevsky A. T. and Head J. W. (1995) *Planet. Space Sci.*, 434, 1523. [6] Basilevsky A. T. (1996) *LPS XXVII*, 67.